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EFFECT OF ELECTRICAL PROCESS PARAMETERS OF ELECTRIC DISCHARGE MACHINE (EDM) ON SURFACE ROUGHNESS AND MATERIAL REMOVAL RATE FOR EN 8 ALLOY STEEL

Vivek Yadav [1] | Mr. Surender Singh [2] | Dr. Bhupender Singh [2]

[1] M.Tech. Student, Department of Mechanical Engineering, YMCA University of Science and Technology, Faridabad.
[2] Assistant Professor, Department of Mechanical Engineering, YMCA University of Science and Technology, Faridabad.

ABSTRACT

In today's time, Non Traditional Machining is best suited for machining exotic engineering metallic materials, composite materials and high tech ceramics having good mechanical properties and thermal characteristics as well as sufficient electrical conductivity.

EDM has become one of the most important and cost-effective method of machining extremely tough and brittle electrically conductive materials. It is widely used in the process of making moulds and dies and sections of complex geometry and intricate shapes. The work piece material selected in this experiment is EN 8 after reviewing all other materials. The input variable parameters are current, voltage, pulse on time and duty factor. Taguchi Method is applied to create an Orthogonal Array of input variables using the Design Of Experiment (DOE). The effect of variable parameters mentioned above upon Material Removal Rate (MRR) and Surface Roughness (SR) is analyzed and investigated. Each set of reading of Orthogonal Array is used by making two cuts of 1 mm depth and weight after first and second cut is checked to calculate average MRR and average surface roughness. Then analysis of the experiment is done in Taguchi to get the trend of MRR and SR with four variable input parameters.

KEYWORDS: EDM, MRR (Material Removal Rate), SR (Surface Roughness), Taguchi Method, OA, S/N Ratio, DOE.

1. INTRODUCTION

Electrical Discharge Machining, (EDM) is a well-known machining technique since more than fifty years. Nowadays it is the most widely-used nontraditional machining process mainly to produce injection moulds and dies, for mass production of very common objects. It can also produce finished parts, such as cutting tools and items with complex shapes. EDM is used in a large number of industrial areas: automotive industry, electronics, domestic appliances, machines, packaging, telecommunications, watches, aeronautic, toys and surgical instruments.

The advantages of EDM over traditional methods such as milling or grinding are multiple. Any material that conducts electricity can be machined, whatever its hardness (hardened steel, tungsten carbide, special alloys for aerospace applications. for example Furthermore, complex cutting geometry, sharp angles and internal corners can be produced. Final surface state with low ridges (< 100 nm) and precise machining (1μm) are other important advantages [1]. Moreover there is no mechanical stress on the machined piece, no rotation of work piece or tool is necessary, and the machines have a high autonomy. On the other hand, the disadvantages are the relatively low material removal rate, surface modification of the machined work piece ("white layer") and heat affected zone, typical depth (50microns), and limited size of work piece and tool [2].

2. EXPERIMENTATION AND METHODOLOGY

2.1. Experimentation

A die- sinking EDM machine (Electronica) was used to conduct the cutting experiments on alloy steel EN 8.The EDM machine is a Z-Axis numerically controlled machine and table feed controlled by stepper motor [3]. The control panel of machine has a provision to set independent voltage, current, pulse-on time and duty factor for the machining process. The time for auto flushing can be set depending on the depth to be flushed.

Table -1: Common features and specifications of EDM machine

Parameters	Range
X×Y×Z	300×200×250
Programmable Axis	Z-Axis
Current	1 to 50 A
Voltage	30 to 120 V
Pulse on time	0.25 to 4000 microseconds
Duty Factor	10 to 100

The work piece should be electrically conductive. EN 8 alloy steel was chosen as work piece material. Size of the work pieces was 50mm ×45mm ×10 mm. Nine different specimens were taken for performing the experiment on EDM. Two cuts on every specimen were given and the average values of MRR and SR were taken for the calculation. Tool material should be electrically conductive so that it can conduct the current through it to the work piece during the machining. A circular shaped copper electrode (9.6 mm diameter) was chosen for machining during experiment. Important electric process parameters for Electrical Discharge Machining are current, voltage, pulse on time, duty factor. So, these four electric process parameters were selected as input parameters to perform the experiment. Material removal rate (MRR) and Surface roughness (SR) were taken as output.

2.2. Methodology

The Taguchi method of optimization is a 3-step process (Jameson (2001), Montgomery (2001), which deals with the selection of raw material at the first stage, based on the engineering properties of that material. At the 2nd stage, the optimization process is carried out on the basis of the design of experiment table. The 3rd stage is the stage, where the comparison between the experimental and the predicted values are done to validate the result [4]. On the basis of the different combinations of inputs obtained by the Taguchi method, the corresponding S/N ratio is generated for the materials (on which experiments are to be done) by the use of Minitab 17 software (Minitab Manual 2010). After the generation of that S/N (Signal to noise ratio) table, the response table for mean S/N ratio for the materials is obtained, on the basis of which the corresponding the rank of the different parameters are used to find the level of importance towards affecting the MRR. A well planned set of experiments, in which all parameters of interest are varied over a specified range, is a much better approach to obtain systematic data [5]. Mathematically speaking, such a complete set of experiments ought to give desired results. Usually the number of experiments and resources (materials and time) required are prohibitively large. Often the experimenter decides to perform a subset of the complete set of experiments to save on time and money! However, it does not easily lend itself to understanding of science behind the phenomenon.

Table-2: Important process parameters and their levels

S. No.	Parameters	Levels		
		1	2	3
A	Current (A)	10	15	20
B	Voltage (V)	35	40	45
C	Pulse on time (μs)	100	500	900
D	Duty Factor	40	60	80

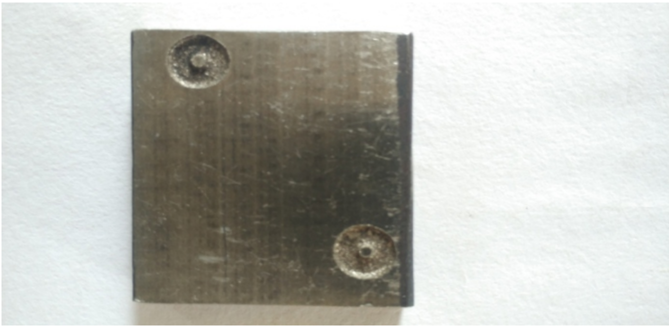

Fig.1- Photographic image of machined work piece

Table-3: Experimental layout/Design using L9 Orthogonal array [6]

Exp. No.	Input parameters			
	Current (A)	Voltage (V)	Pulse on time (µs)	Duty Factor
1	10	35	100	40
2	10	40	500	60
3	10	45	900	80
4	15	35	500	80
5	15	40	900	40
6	15	45	100	60
7	20	35	900	60
8	20	40	100	80
9	20	45	500	40

At these sets of value, experiments were conducted on nine different specimens. Machining was done two times at one set of value to get the better results. Then surface roughness and material removal rate were calculated from both the cuts. Average values were taken from two readings. These average values were then used in analyzing the results obtained experiments.

SURFACE ROUGHNESS MEASUREMENT

Surface Roughness indicates the state of a machined surface i.e. whether the machined surface is having irregularities or not. Surface roughness can be examined by eye or rubbed with fingertip, if irregularities are more on the machined surface. But, to get the exact value of surface roughness we need a surface roughness tester.

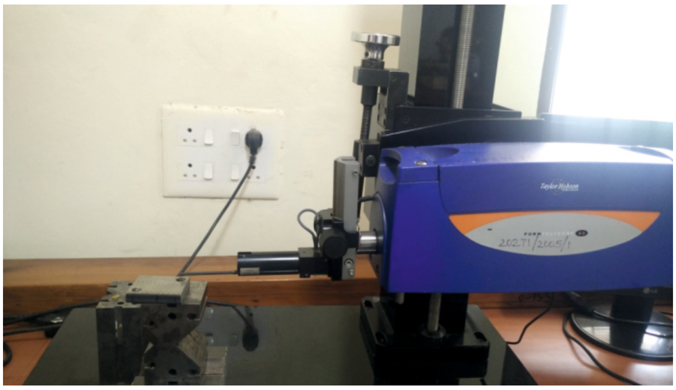

Fig.2: Photographic image of surface roughness tester

Part of the surface roughness tester which comes in contact with machined surface (which is going to be tested), is called stylus. Stylus can be made of different material (according to the requirement). When stylus moves up and down along with the work surface perpendicularly, its motion is converted in electric signal, which are amplified, filtered & transformed into digital signals through A/D (Analog to Digital) converters. The signals are then processed by CPU in Ra values before being displayed on the screen. Value of Surface roughness is measured in micro meter (µm).

The quality characteristics of these responses are shown below:

Quality characteristics of response parameters:

Table-4: Quality characteristics of response parameters

Output response parameters	Response characteristics
MRR	Larger-the-better
SR	Smaller-the-better

3. RESULTS AND DISCUSSIONS

After machining of EN 8 alloy steel, Material Removal Rate and Surface Roughness were measured. Both MRR, SR, time of machining with other values are shown in the table -5. Two cuts were given to all the specimens. So, the values of time of machining, Material Removal Rate, Surface Roughness are the average values of both the cuts. Input parameters were current, voltage, pulse on time, and duty factor. Output responses were MRR & SR. Three levels of all input parameters were selected. Design of the experiment was done with the help of Minitab software and Taguchi method was used for finding the effect of those input parameters on surface roughness & material removal rate [7].

Table-5: Input parameters and output responses

Exp No.	Input Parameters				Output Response			
	Current (A)	Voltage (V)	Pulse on time (µs)	Duty Factor	Avg. Time of Machining (from both the cuts) (min.)	Avg. Value of Wt. Removed (from both cuts) (grams)	MRR (Avg. of both cuts) (mm3/min.)	SR (Avg. Of both cuts) (µm)
1	10	35	100	40	5.8750	0.5342	11.6392	6.2044
2	10	40	500	60	2.9750	0.5579	24.3213	7.6431
3	10	45	900	80	2.2184	0.5265	30.9013	6.4709
4	15	35	500	80	1.5500	0.5368	44.5138	10.3859
5	15	40	900	40	4.0500	0.5227	16.9704	10.6702
6	15	45	100	60	1.8484	0.5422	38.0770	8.0739
7	20	35	900	60	1.6500	0.6571	51.4427	10.9355
8	20	40	100	80	0.9417	0.5364	73.0307	10.7409
9	20	45	500	40	1.9834	0.4862	31.3234	8.5517

Analysis of results was done by MINITAB software. These analysis are done by plotting graphs. The graphs are plotted for means and for S/N (Signal to Noise) ratio.

Graphs were plotted for MRR and for SR at means & at S/N ratio. Graphs plotted were for all the input parameters i.e. effect of all four process parameters on MRR &SR can be shown with the help of graphs.

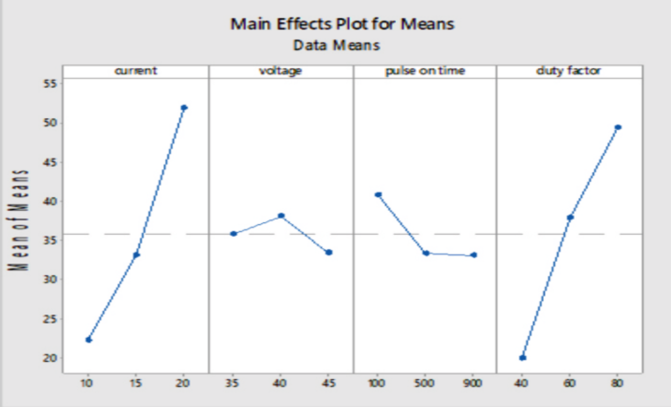

Fig.3: effect of process parameters on MRR for means

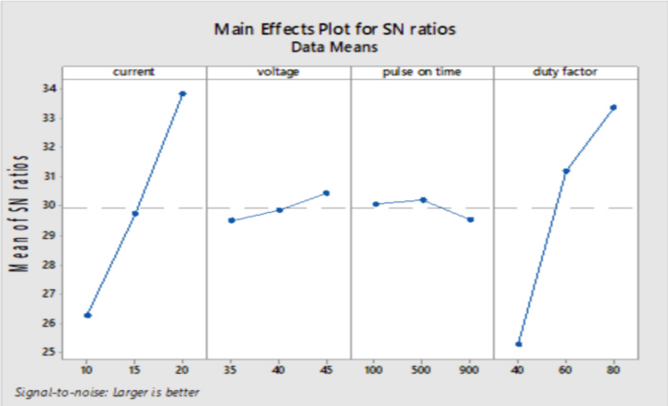

Fig.4: effect of process parameters on MRR for S/N ratio

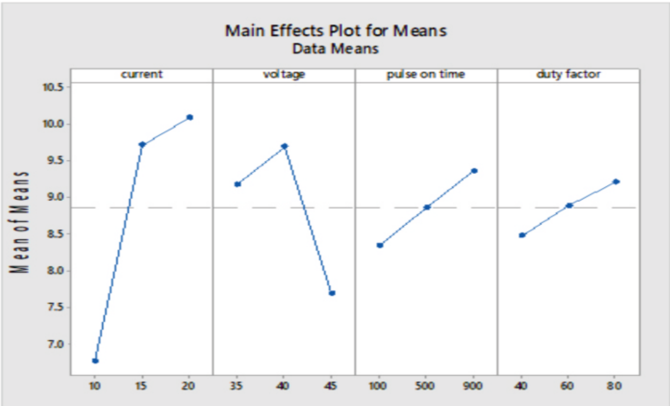

Fig.5: effect of process parameters on SR for Means

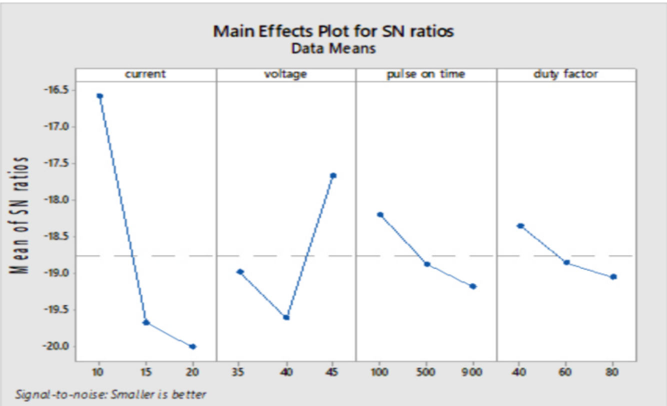

Fig.6: effect of process parameters on SR for S/N Ratio

4. CONCLUSIONS

Based on the conducted experiments the following conclusions can be made

1. As current increases, MRR also increase with almost same rate.
2. With increase in voltage, MRR increases firstly with a slower rate, then at a slightly faster rate.
3. MRR firstly increases with pulse on time but then decreases.
4. MRR increases with Duty factor firstly at a faster rate and then at a slower rate.
5. Surface Roughness increases with increase in current.
6. As voltage increases, Surface roughness first increases and then decreases.
7. With increase in pulse on time, there is increase in Surface Roughness at a constant rate.
8. Surface Roughness increases with increase in duty factor.

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